PUBLIC SAFETY PSWN PROGRAM WIRELESS NETWORK

Saving Lives and Property Through Improved Interoperability

Commercial Services Report #3: Specialized Mobile Radio, Enhanced Specialized Mobile Radio and Mobile Satellite Service Assessment

FINAL

March 2002

Foreword…

THE SPECIALIZED MOBILE RADIO (SMR), ENHANCED SPECIALIZED MOBILE RADIO (ESMR), AND MOBILE SATELLITE SERVICE (MSS) ASSESSMENT REPORT PROVIDES AN UPDATE ON THE STATUS OF VARIOUS WIRELESS-BASED COMMUNICATIONS TECHNOLOGIES

- This report is part of a three-report series targeting commercial services and their applicability to public safety missions
  - Provides a broad assessment of the current state of the SMR, ESMR, and MSS industries
  - Does not reflect a government position, nor is it intended to offer the Public Safety Wireless Network (PSWN) Program's endorsement for any particular service provider or vendor

- This single consolidated report serves as an update and replacement for two PSWN Program Year 1 (1997) documents that addressed SMR, ESMR, and MSS. Note: Where industry information reported in the earlier documents is unchanged, but still relevant, that information is included in this report for ease of reference

- Comments regarding the information provided in this document may be directed to the PSWN Program Management Office (PMO) at 1-(800)-565-PSWN, or by e-mail to information@pswn.gov

- For additional PSWN Program information and research, visit the home page at http://www.pswn.gov

Outline of Contents

EXECUTIVE SUMMARY

THIS REPORT EXAMINES SEVERAL METHODS OF PUBLIC SAFETY COMMUNICATIONS THROUGH USE OF ALTERNATIVE COMMERCIAL WIRELESS SERVICES

- Wireless services listed in this report that strengthen public safety capabilities in a mobile environment include
  - Specialized Mobile Radio—SMR can be defined as a two-way radio system in which two or more mobile wireless transceivers are linked by a single base station. SMR systems are similar to cellular systems; however, SMR networks provide coverage via a single base station (i.e., multiple base stations and repeaters are not used) implying that the coverage is much more limited than that of cellular service. Outside connectivity to land-line telephones may also not exist
  - Enhanced Specialized Mobile Radio—ESMR can be defined as a commercial wireless communication system in which numerous mobile or portable transceivers are wirelessly linked to networked groups of repeaters. ESMR systems offer greater flexibility because they include telephone connectivity and enhanced services similar to cellular systems
  - Mobile Satellite System—MSS can be defined as networks of orbiting communications satellites intended for use with mobile and portable wireless telephones. Satellites provide communication links with handsets in a similar fashion to that of cellular systems, with the primary difference being that the repeaters are at a much larger distance away (above the earth)

- Commercial wireless services can assist in delivering invaluable information to field personnel while, at the same time, alleviating congestion of the limited amount of spectrum that each agency must share; however, agencies must consider several factors when planning to implement wireless data technologies
  - Coverage—The new service should provide coverage required in the current jurisdictional area
  - Capacity—The new service should aid in expanding the current system's resources by transferring two-way or private conversations to alternate resources. Also, the capacity of the new service should be considered in emergency scenarios if the current system became unavailable
  - Security—The new services should ensure the same or better security measures as the current system unless separate tasks for the new service are not in need of enhanced security
  - Reliability—The new service should be proven in the field in similar applications
  - Cost—The capabilities and features should justify the purchase of the new service

THIS REPORT DETAILS THE ANALYSIS PERFORMED TO EVALUATE POTENTIAL USE OF COMMERCIAL WIRELESS SERVICES

- Data from several sources was analyzed in developing this report, leading to an assessment based on key findings. The analysis followed the process outlined below:
  - Data gathering—Included performing a gap analysis on the Public Safety Wireless Network (PSWN) Program's Year 1 reports on commercial services, and then gathering input from professional societies, textbooks, technology forums and vendor Web sites
  - Analysis—SMR, ESMR, and MSS technologies then were assessed relative to the Cost, Accessibility, Reliability, Technology, and Security (CARTS) model
  - Results—Results from the analysis reflect the primary factors that local, state, and federal users should consider when weighing options for implementing commercial wireless solutions

RESULTS OF THE ASSESSMENT ARE SUMMARIZED WITH SHADED CIRCLES

Technology	Cost	Availability	Reliability	Technology	Security	Overall Rating	Comments
SMR	◑	○	◑	●	○	◑	SMR service can be a basic, easy-to-use technology that provides voice communications, although coverage can suffer in certain areas. Cost is a disadvantage because equipment and service costs are higher than the advanced and larger scale ESMR technology. Availability is limited and dependent on vendor services in specified areas; however, reliability is proven in the field and a good backup, however, there are possibilities of degradation. The technology is easy to use and requires little maintenance. Finally, security is minimal because most communications are performed using simple analog methods. Overall, SMR technology is similar to private LMR systems, and other services should be researched
ESMR	●	◑	◑	●	◑	◕	ESMR service has average reliability, is inexpensive, and is an easy-to-use service with many enhanced features that can be very helpful to field personnel. Overall cost is inexpensive with a minimal expense per month per user, and a relatively inexpensive telephone can be purchased. ESMR users are subject to network congestion or overcrowding of channels in emergencies. Coverage is not available on a national basis, although most major U.S. cities are covered, including service in other GSM-equipped countries. ESMR security is greater than SMR due to digital encoding methods; however, a standard method of encryption is not employed and information passed through the system is unencrypted and vulnerable to interception. Overall, this technology rates well for a public safety user
MSS	◔	◑	●	●	◑	◑	MSS service is a very useful tool in emergency situations when terrestrial coverage, congestion, or capacity limits communications for a mobile user. In the past, MSS per-minute rates were relatively expensive (as compared to other wireless services) and were therefore mostly used as an emergency form of communications. However, as usage costs continue to decline, MSS is being used more and more as a means for administrative communications. Coverage is usually excellent in an outdoor environment, and outages rarely occur in satellite equipment. The inability to communicate indoors, however, limits use. Satellite communications technology has been available for many years, proving its capabilities. Communications in this technology, like any other voice communications are vulnerable; however, digital technology provides better security and helps to limit intrusions. MSS is a valuable service for any large organization facing the potential for downed communications during an emergency

○	◔	◑	◕	●
Least Favorable	Less Favorable	Average	More Favorable	Most Favorable

I. INTRODUCTION

PUBLIC SAFETY AGENCIES THROUGHOUT THE UNITED STATES HAVE DEMONSTRATED AN INHERENT NEED FOR COMMUNICATIONS SERVICES THAT SUPPLEMENT AGENCY-OWNED LAND MOBILE RADIO (LMR) SYSTEMS

- The public safety community is continually improving its ability to complete its mission to protect life and property. Communications technology is a tool used to support that mission. This report examines three types of communications technologies that can be used to support the public safety mission: specialized mobile radio (SMR), enhanced specialized mobile radio (ESMR) service, and mobile satellite service (MSS) are very helpful components of communications that assist in fulfilling a public safety mission

- An agency using SMR, ESMR, or MSS technology has the potential to communicate in several ways with internal staff or other jurisdictions and agencies
  - Field personnel can simply call another agency's field personnel from an ESMR or MSS telephone through a Public Switched Telephone Network (PSTN) when participating in a mutual-aid event
  - An agency can patch an ESMR telephone or an MSS telephone into another system's console through a modular interface or interconnect system
  - Interagency field personnel can use ESMR as an alternate and more private two-way radio system instead of using the agency-provided system. For this connection, the two communicating parties must be using the same proprietary commercial system
  - Traditional SMR service is similar to private LMR because it primarily offers voice dispatch service within a local area. SMR, however, does have the capability of being patched to external systems

- This report serves as a guide to help public safety coordinators understand SMR, ESMR, and MSS systems and technologies. The report can also serve as a primer for a coordinator to use in understanding plans to purchase a new service or equipment

II. BACKGROUND

SMR, ESMR, AND MSS TECHNOLOGIES CAN ENABLE A PERSON OR AN AGENCY TO PERFORM THEIR MISSIONS MORE EFFECTIVELY AND EFFICIENTLY

- SMR can be defined as a two-way radio system in which two or more mobile or portable wireless transceivers are linked by a single base station. SMR systems are similar to cellular systems, however, SMR networks provide coverage via a single base station (i.e., multiple base stations and repeaters are not used) implying that the coverage is much more limited than that of cellular service

- EMSR can be defined as a commercial wireless communication system in which numerous mobile or portable transceivers are wirelessly linked to networked groups of repeaters. ESMR systems offer a great amount of flexibility including telephone connectivity and enhanced services similar to cellular systems

- MSS can be defined as networks of orbiting communications satellites intended for use with mobile and portable wireless telephones. Satellites provide communication links with handsets in a similar fashion to that of cellular systems, with the primary difference being that the repeaters are at a much larger distance away (above the earth)

- Private LMR communications systems are often very effective in communicating messages; however, today's LMR communications systems have a few disadvantages
  - Because of a combination of limited radio spectrum and a large number of users, LMR voice systems can have high levels of congestion during periods of peak use
  - Due to the possibility of congestion, LMR users usually limit the time that they use their radios, therefore limiting their means to communicate information - because of this, agencies are looking to commercial services to provide an additional means of communication

- Alternate communication methods, such as SMR, ESMR, and MSS, have many benefits
  - Since field personnel would not have to return to the office as often or look for a land line telephone to make calls, public safety personnel would likely have an increased presence in the field when possessing an ESMR or satellite telephone
  - Field personnel can use portable telephones for non-emergency, non-tactical, and administrative calls
  - Commercial services can be used in emergency situations when the existing LMR infrastructure is either difficult to access or is completely unavailable because of a lack of coverage or a highly congested system

III. METHODOLOGY

A FOUR STEP PROCESS WAS USED TO COMPLETE THE ASSESSMENT OF SMR, ESMR, AND MSS TECHNOLOGIES

- Data gathering
  - Analysts used PSWN Program Year 1 reports for initial subject matter
  - Analysts filled information gaps and gathered technology updates for each subject from various professional societies, textbooks, technology forums, and vendor Web sites

- Analysis of SMR, ESMR, and MSS technology and services
  - Communications technologies such as the Global System for Mobile Communications (GSM), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA) are presented as multiple access methods used in their respective services. Multiple access methods are used to increase user concentrations in a specific area
  - Following a review of current communications technologies, SMR, ESMR, MSS service characteristics were presented and assessed according to the Cost, Accessibility, Reliability, Technology, and Security (CARTS) model

- Discussion of how SMR, ESMR, and MSS services play a role in public safety
  - This report analyzes local, state, and federal public safety agencies' requirements relative to SMR, ESMR, and MSS applications

- Development of wireless communications assessment
  - The report assesses these wireless services based on potential public safety needs and requirements
  - A one-page outline summarizes key findings regarding SMR, ESMR, and MSS

IV. SMR, ESMR, AND MSS PUBLIC SAFETY REQUIREMENTS

OVERALL, PUBLIC SAFETY PLANNERS SHOULD ADDRESS FIVE KEY CRITERIA WHEN CONSIDERING COMMERCIAL SERVICES FOR USE IN PUBLIC SAFETY MISSIONS—COST, AVAILABILITY, RELIABILITY, TECHNOLOGY, AND SECURITY

- This section examines each of the wireless services described in this report

- Each identified wireless service is evaluated based on the five key criteria
  - **Cost** – based on costs involving user equipment, service fees, and communications center equipment, a three-level cost analysis is used to assess each service. A cost benefit analysis should be performed before beginning the any procurement processes
  - **Availability** – A specific technology must be readily available and must be able to sustain public safety operations. The technology must therefore be designed to provide adequate coverage and capacity during normal day-to-day operations or during emergencies. The technology must also be scalable to provide communications for additional personnel when necessary.
  - **Reliability** – A public safety user may operate indoors or outdoors, thus, wireless technologies must be capable of operating in many varied conditions in a mobile and portable environment. The trusted reliability of a given technology must be considered when purchasing equipment and services
  - **Technology** – A new technology must be effective for use in emergency incident response, add value to mission requirements, and enhance job performance
  - **Security** – The ability to mitigate communication path vulnerabilities is one of the most important requirements of any system. At any point between communication devices, a message could potentially be intercepted, spoofed, or otherwise interrupted

- Shown below is a table of keys used to rate each requirement and a chart evaluating how well each technology would satisfy a particular requirement in a public safety environment

OVERALL, PUBLIC SAFETY PLANNERS SHOULD ADDRESS FIVE KEY CRITERIA WHEN CONSIDERING COMMERCIAL SERVICES FOR USE IN PUBLIC SAFETY MISSIONS—COST, AVAILABILITY, RELIABILITY, TECHNOLOGY, AND SECURITY (CONTINUED)

Cost — Each of the identified services is assessed based on the following cost categories:	
●	Low Cost—The equipment is low in cost (approximately $1,000 or lower in cost) with minimal recurring fees
◑	Medium Cost—The equipment is somewhat expensive (in the range of $1,000 to $2,500)
○	High Cost—The equipment tends to be quite expensive (more than $2,500)
Availability — Each of the identified services is assessed based on the following availability categories:	
●	High—A system can pass all communications between the transmitter and the receiver with little or no disruptions
◑	Medium—The technology is very helpful and rarely has disruptions in service
○	Low—The technology has limited use when compared with current technology standards
Reliability — Each of the identified services is assessed based on the following reliability categories:	
●	High—A technology that has proven reliability, has redundancy, and is supported by several government agencies
◑	Medium—A technology that has some reliability and redundancy; however, it can encounter some degradations
○	Low—A technology that has not been proven in the field, especially for public safety missions
Technology — Each of the identified services is assessed based on the following technology categories:	
●	Favorable—A powerful technology that serves many applications, is easy to use, and requires little human interaction
◑	Neutral—The technology is useful; however, it may require training or need an on-site expert
○	Unfavorable—The technology has limited features or applications and may be difficult to learn or to use
Security — Each of the identified services is assessed based on the following security categories:	
●	High—One of the best encryption standards available
◑	Medium—Security is enabled; however, it is relatively easy to intercept with the proper surveillance equipment
○	Low—Little or no security is available

THE FOLLOWING CHART SUMMARIZES THE ASSESSMENT OF EACH SERVICE AGAINST EACH REQUIREMENT BASED ON THE KEYS DISCUSSED

Technology	Cost	Availability	Reliability	Technology	Security	Overall Rating	Comments
SMR	◑	○	◑	●	○	◑	SMR service can be a basic, easy-to-use technology that provides voice communications, although coverage can suffer in certain areas. Cost is a disadvantage because equipment and service costs are higher than the advanced and larger scale ESMR technology. Availability is limited and dependent on vendor services in specified areas; however, reliability is proven in the field and a good backup, however, there are possibilities of degradation. The technology is easy to use and requires little maintenance. Finally, security is minimal because most communications are performed using simple analog methods. Overall, SMR technology is similar to private LMR systems, and other services should be researched
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V. SMR, ESMR, AND MSS COMMUNICATIONS TECHNOLOGIES

THIS SECTION DISCUSSES THE FOLLOWING TOPICS RELATING TO THE GENERAL AREAS OF SMR, ESMR, AND MSS TECHNOLOGIES

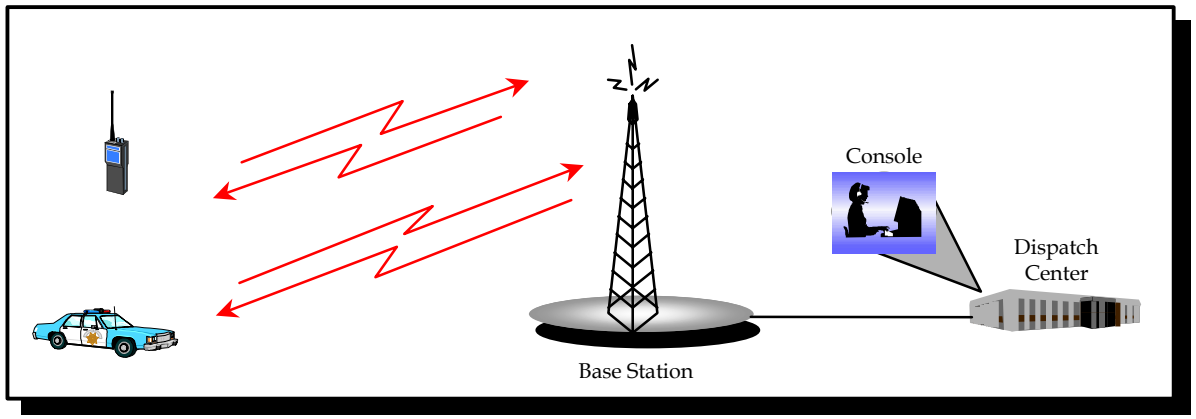
- Overall, general descriptions of the technologies
- Network perspectives and diagrams
- Spectrum allocation information
- Air interface technologies

SMR SERVICES ARE USEFUL FOR SUPPLEMENTING PUBLIC SAFETY AGENCIES' LMR SYSTEMS BY PROVIDING ADDITIONAL COMMUNICATIONS SUPPORT

- SMR is a commercial wireless service that provides mobile dispatch and data communication services. Dispatch services allow users to communicate with a single radio, simultaneously with all radios, or with a subgroup of radios in a group

- A traditional SMR system consists of one or more base station transmitters, one or more antennas, and end-user radio equipment that usually consists of a mobile radio unit either provided by the end user or obtained from the SMR operator for a fee. SMR end users may operate in either an "interconnected" mode or a "dispatch" mode
  - Interconnected mode provides a connection between mobile radio units and the PSTN. Thus, an end user may transmit a message with his or her mobile radio unit to the SMR base station. The call will then be routed to the local PSTN. This allows the mobile radio unit to function as a mobile telephone
  - Dispatch mode allows two-way, over-the-air, voice communications between two or more mobile units or between mobile units and fixed units

- As a supplement to a public safety agency's LMR system, SMR increases that agency's available spectrum for conversations that are important but not emergency oriented

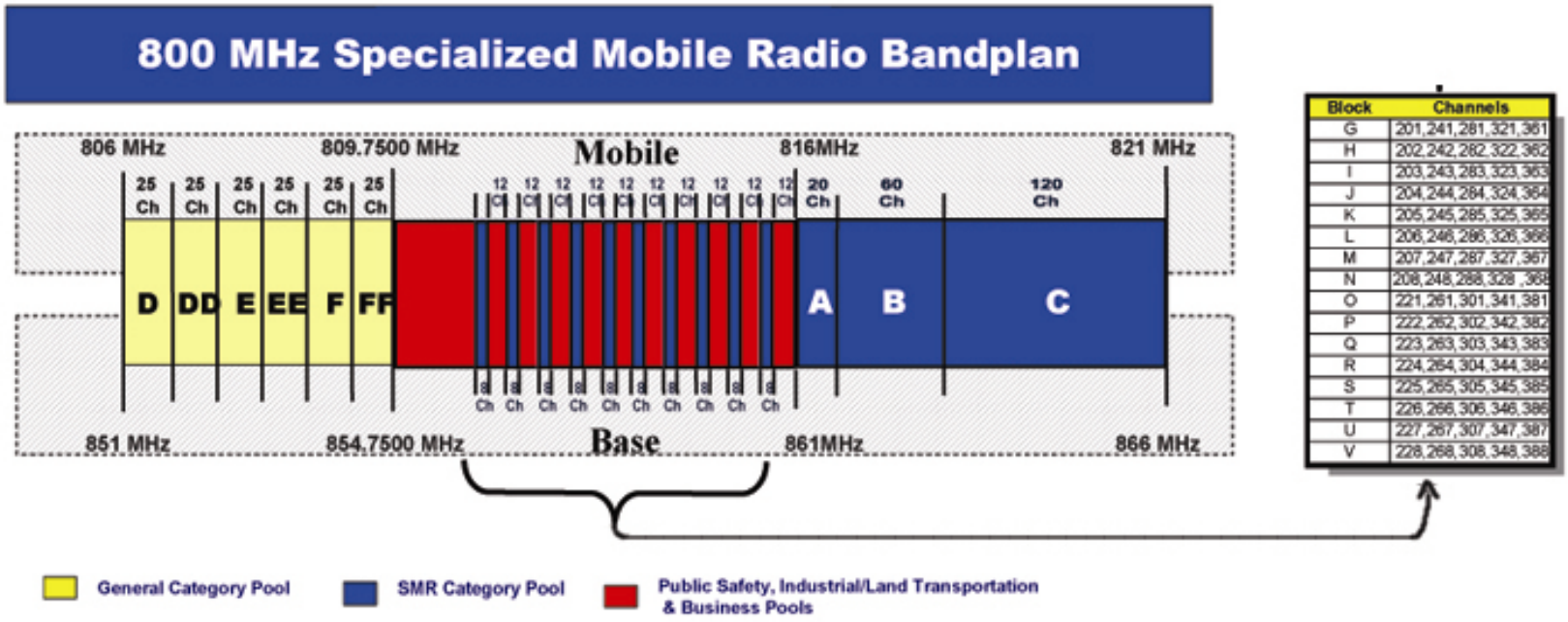


BECAUSE SMR TRANSMITS IN A LIMITED GEOGRAPHICAL AREA, SPECTRUM IS LICENSED TO SYSTEMS ON VARIOUS ALLOCATIONS OF THE LAND MOBILE SECTOR

- SMR services primarily exist in the very high frequency (VHF), ultra high frequency (UHF), and 800 MHz ranges

- SMR systems use 25 MHz channel pairs—each transceiver has a transmit frequency and a receive frequency
  - These frequencies differ by a fixed amount, called the offset
  - The offset frequencies are in the same band, that is, relatively close to each other in the radio spectrum

- Recent U.S. Federal Communications Commission (FCC) frequency allocation auctions have awarded 525 licenses for 800 MHz SMR, as shown below, through a simultaneous multiple round auction



- Courtesy of the Federal Communications Commission

ESMR SERVICES ARE BECOMING AN INCREASINGLY IMPORTANT COMMUNICATION TOOL FOR GOVERNMENT, BUSINESS, AND PRIVATE USERS

- ESMR is a commercial wireless communication system in which numerous mobile or portable transceivers are linked in a network of repeaters
  - Each repeater has a range of approximately 500 feet to 10 miles
  - Operating frequencies are usually in the 800 to 900 MHz band
  - ESMR functions like its predecessor, specialized mobile radio (SMR), but with many additional features, some of which are similar to those of cellular systems

- In addition to mobile telephone service, ESMR provides three to four other forms of communications that may appeal to a public safety user
  - Digital dispatch allows two users, or large groups of users called talk groups, to communicate with each other in a push-to-talk manner across the ESMR service provider's coverage area
  - Cellular-like telephone connectivity allows communications via the PSTN
  - Alphanumeric short message services allow users to send short text messages
  - E-mail and Internet pages can be accessed through a specially built browser within the telephone
  - ESMR subscribers can also choose from a variety of optional digital service features, such as call waiting, call hold, voice mail, and caller identification (ID)

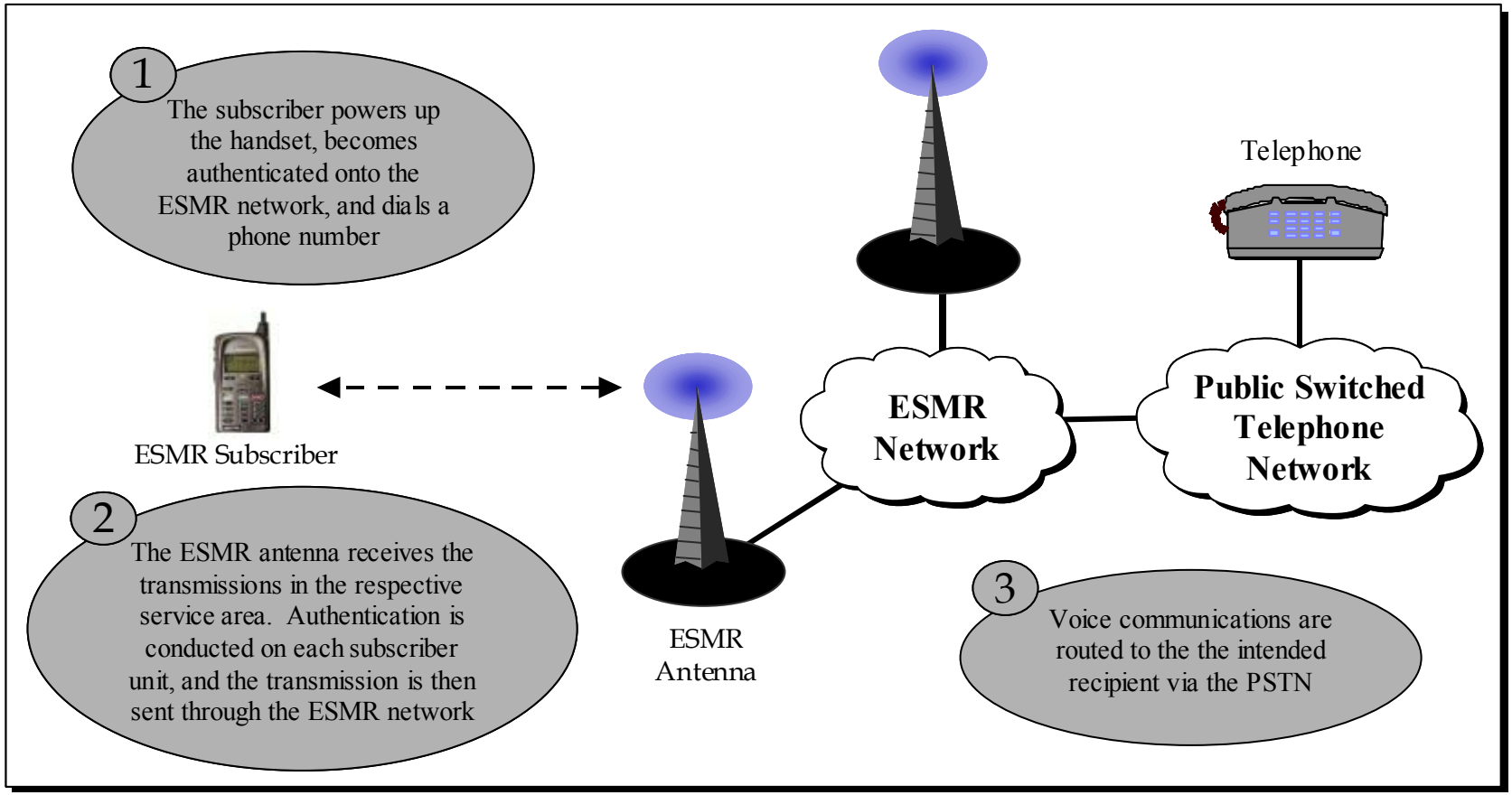
ESMR COMMUNICATIONS SYSTEMS ARE WIRELESS NETWORKS COMPOSED OF LOW-POWER TRANSMITTER SITES, WITH SMALL COVERAGE FOOTPRINTS SIMILAR TO TELEPHONE SYSTEMS

- Wireless networks use the concept of dividing a geographical area into a series of small coverage areas (i.e., cells)
  - User terminals communicate with antenna sites (or base stations) covering each geographical region
  - The antenna sites are connected to a control point, the mobile switching center (MSC), by conventional telephone lines or via microwave radio frequency (RF) links
  - The MSC constantly monitors signal strength
    - When the user crosses a cell boundary, the MSC can “hand off” the call from one base station to the next without disrupting conversation
    - The MSC also routes calls to other subscribers or to the PSTN
    - As a result of differing topography, the population density of the area served, and other limiting factors, the radius of a cell can range from 500 feet to 10 miles
    - An additional responsibility of an MSC with regard to ESMR is the setup of a talk group. The talk group resembles a conference call, except the call is only half-duplex, i.e., only one message can be sent at a time among all participants

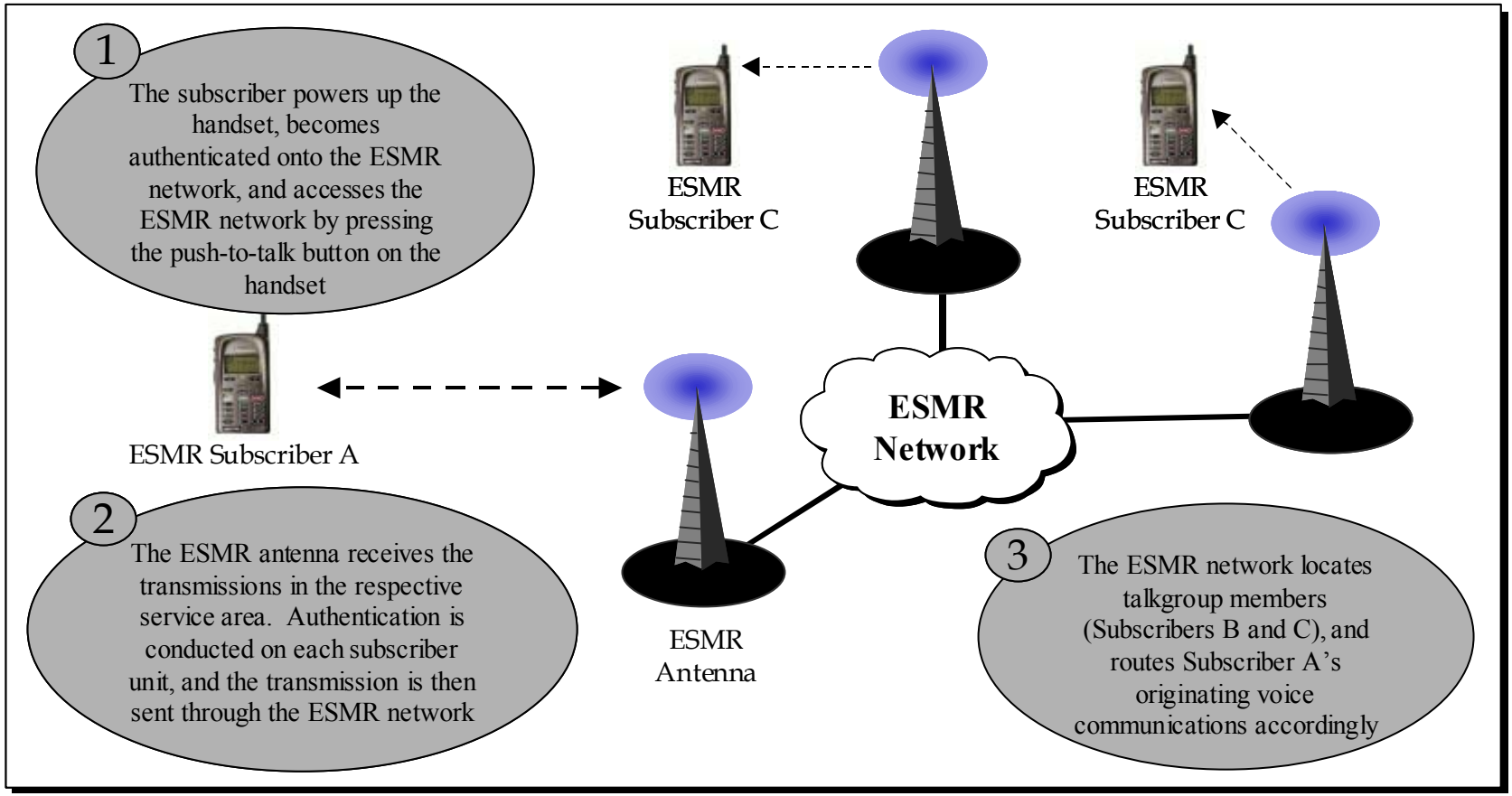
- Each service provider offers mobile coverage for users traveling within its cells (i.e., service coverage area)

- ESMR integrates the functionality of digital cellular service and dispatch networks
  - All ESMR communications are carried through the ESMR network of repeaters
    - There is no talk-around capability (i.e., no ability for two or more subscriber devices to directly communicate without the assistance of network infrastructure)
    - When operating in a public safety environment, the cellular function can dramatically tie up resources due to phone services occupying the majority of the RF time

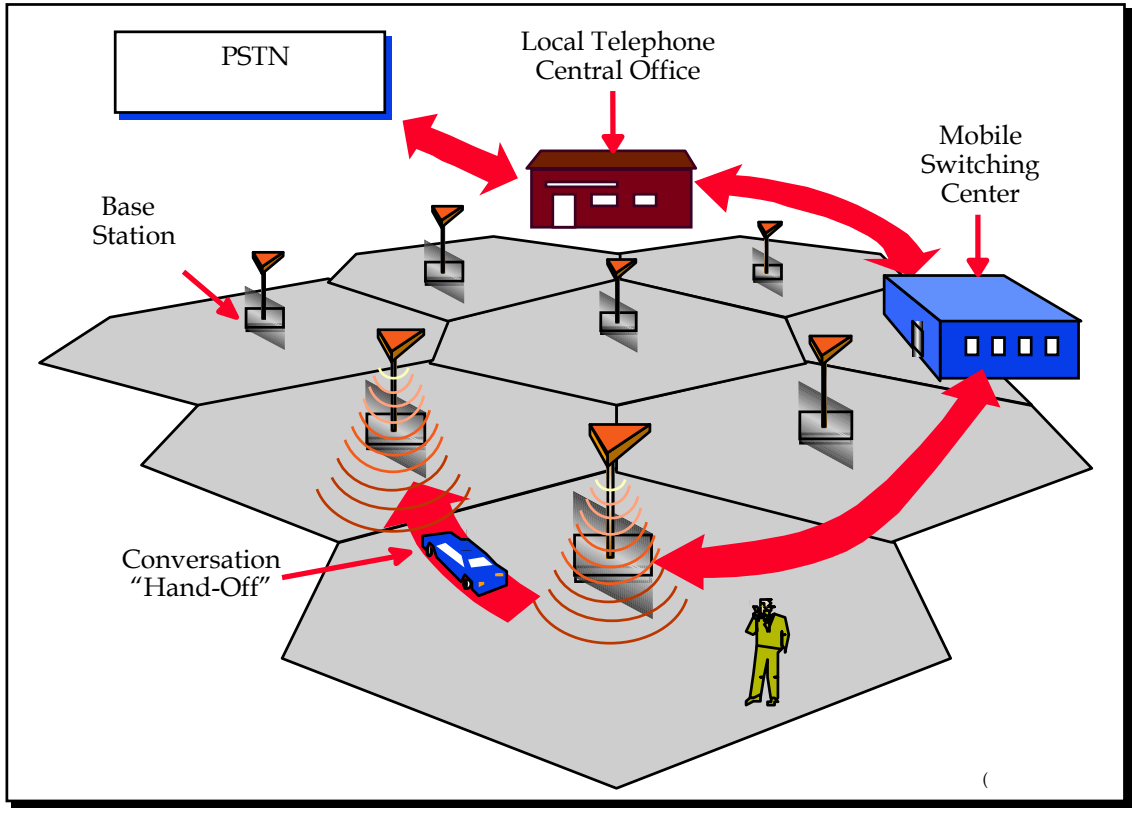
SHOWN BELOW IS A DIAGRAM OF AN ESMR DIGITAL TELEPHONE CALL FROM A NETWORK PERSPECTIVE



SHOWN BELOW IS A DIAGRAM OF AN ESMR DISPATCH CALL FROM A NETWORK PERSPECTIVE



ESMR INVOLVES A SIMILAR TYPE OF INFRASTRUCTURE DESIGN AS THAT USED BY CELLULAR AND PERSONAL COMMUNICATIONS SERVICES (PCS) PROVIDERS. SHOWN BELOW IS A FIGURE DEPICTING A BASIC CELLUAR TYPE SYSTEM ARCHITECTURE



ESMR USES TWO BANDS OF 25 MHz THAT HAVE BEEN SET ASIDE FOR USE IN ALL COUNTRIES PARTICIPATING IN A COMMON INTERFACE TECHNOLOGY

- Currently, ESMR service providers primarily employ GSM technology. The service providers in the United States are using the same frequencies as all other countries using this GSM technology. This allows for a United States service provider's phone to co-exist in other countries using a dual mode enhancement

- The 890–915 MHz band is used for subscriber-to-base transmissions (reverse link)

- The 935–960 MHz band is used for base-to-subscriber transmissions (forward link)

- The available forward and reverse frequency bands are divided into 200 kilohertz (kHz) wide channels called Absolute Radio Frequency Channel Numbers (ARFCN)
  - The ARFCN denotes a forward and reverse channel pair that is separated in frequency by 45 MHz
  - Each channel is time shared between as many as eight subscribers using time division multiple access (TDMA) technology

- Recent U.S. FCC frequency allocation auctions have introduced new frequency possibilities in the 700 MHz band
  - No current uses of the spectrum have been implemented at the time of this report, although the frequencies have been awarded to ESMR service providers
  - Results from auctioning this spectrum to ESMR providers creates more channels for providers to use in a given area, hence allowing a larger user base with less interference

REALLOCATING 700 - 900 MHZ BAND SPECTRUM TO REDUCE ESMR INTERFERENCES WITH PUBLIC SAFETY RADIO SYSTEMS HAS BEEN PROPOSED

- According to a Business Wire news release in November of 2001, two objectives have recently been defined in a private corporation's proposal towards improving interference related problems
  - An initial framework was proposed to mitigate interference in public safety communications from commercial services at 800 MHz
    - » Separate channel blocks used by cellular and ESMR providers would be separated from public safety communications systems
    - » Spectrum allocation at 800 MHz would double, thereby providing opportunities to increase capacity, deploy advanced technologies and enhance interoperability among police, fire, and rescue personnel
  - The proposal would essentially realign the 700, 800, and 900 MHz bands
    - » If adopted, public safety communications systems would have access to a 20 MHz block of contiguous spectrum in the lower 800 MHz band – more than double the current allocation of 9.5 MHz of non-contiguous spectrum at 800 MHz
    - » Spectrum allocated in this range would be adjacent to the 700 MHz frequency band already allocated for public safety usage
    - » In return for this spectrum, the service provider would receive 16 MHz of spectrum, comprised of 6 MHz in the upper 800 MHz band and 10 MHz in the 2.1 GHz band[1]

- This proposal could cause a problem for public safety agencies. Communication equipment may have to be altered to operate in the new spectrum. Changing or altering this equipment could possibly increase local, state, and federal public safety costs. To help mitigate these costs, however, funds totaling $500 million have been earmarked to pay down the cost of migrating to the new spectrum

[1] http://www.corporate-ir.net/ireye/ir_site.zhtml?ticker=NXTL&script=410&layout=7&item_id=229661

ESMR RELIES ON ADVANCED PROPRIETARY TECHNOLOGY USING COMMON U.S. AIR INTERFACE TECHNOLOGIES AS ITS BASIS; THERE IS, HOWEVER, NO INDUSTRYWIDE STANDARD

- The most common interface of an ESMR network is the Global System for Mobile Communications (GSM) interface
  - GSM is a digital communications technology developed in the early 1980s to allow roaming throughout Europe. This technology is a Time Division Multiple Access (TDMA)-based approach in which voice transmissions are digitally encoded via a unique encoder designed to emulate the characteristics of human speech. This method of transmission permits a very efficient ratio of data rate to information content
    - » A GSM TDMA frame consists of 124, 200 kHz uplink and downlink channels subdivided into time frames and repeated continuously
    - » TDMA architecture allows for simple transmitter hardware slots for uplink and downlink of a physical time divided channel, which are separated in frequency. Time-divided frames are then shifted in three acknowledgement slots, which allows for a simple type of half-duplex transmitter switching between a receiver and a sender
    - » This technology also allows for greater expandability to incorporate data services such as e-mail, Internet, and instant messaging services
  - The worldwide market figures for mobile telephone networks state that the most popular digital system is GSM, with approximately 40 percent (more than 60 million users) of the market share
  - The U.S. and Canadian market figures state that digital usage is split among TDMA, Code Division Multiple Access (CDMA), and GSM. GSM has an estimated 2 million users in the U.S. and Canada[2]

[2] Schiller, Jochen, Mobile Communications

MSS IS A VERY IMPORTANT COMMUNICATION TOOL FOR GOVERNMENT, BUSINESS, AND PRIVATE USERS IN EMERGENCY SITUATIONS IN OUTDOOR AND REMOTE AREAS OF THE WORLD

- MSS is the term used to describe a commercial wireless communication system in which numerous orbiting satellites act as mobile or stationary repeaters, relaying messages to terrestrial users
  - Each repeater has a line of sight (LOS) range anywhere from 700 to 22,000 mile orbits
  - Operating frequencies are usually in the 1 to 2 GHz band
  - MSS functions similarly to cellular telephony; however, factors such as time delay, transmit and receive power, and Doppler effects are introduced that are not common in terrestrial communications
  - Technology advances in satellite and antenna designs have overcome many of the limitations associated with providing satellite access to a mobile user. Satellites are becoming more sophisticated, more powerful, and smaller. Similarly, user terminals are becoming smaller, more user-friendly, and easier to obtain. As the technology advances, MSS equipment and service prices are becoming more reasonable, making MSS more accessible to the average user.

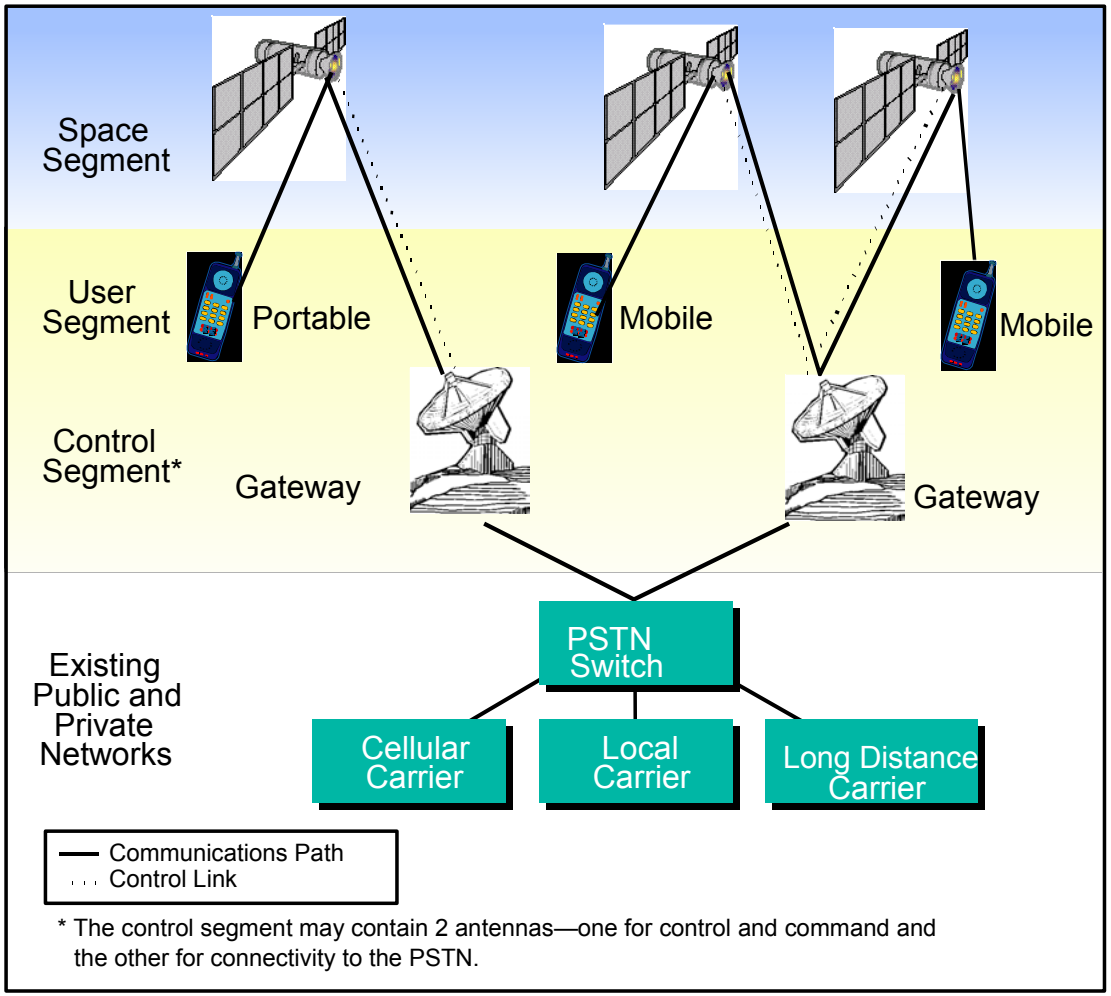
- MSS supports both voice and data communications
  - Approximately seven commercial satellite systems provide either global or North American service
  - While MSS is expected to fill the gaps in wireless voice telephony coverage and complement existing terrestrial wireless or PSTN services, it may compete directly with existing terrestrial services in some areas
  - MSS services will include voice, low-speed data, fax, paging, high-speed data, and broadcast and video on demand; specific services will likely vary among MSS providers
  - Several telephones provide terrestrial service combined with satellite service, using terrestrial service whenever available

MSS SYSTEMS CONSIST OF SATELLITE NETWORKS CALLED CONSTELLATIONS, WITH EACH CONSTELLATION PROVIDING A LARGE "FOOTPRINT" OF GLOBAL OR NATIONAL COVERAGE, DEPENDING ON THE SPECIFIC DESIGN

- Typical communication satellites consist of groups of active microwave repeaters, also known as transponders, with each satellite containing 20 to 50 transponders
  - A satellite transponder receives signals from an Earth transmitter, amplifies the signal, translates the signal to another frequency, and then retransmits the signal to an MSS gateway or directly to another MSS subscriber on Earth
  - Signal amplification is required at the satellite and receiving gateway to counteract signal degradation caused by path loss, atmospheric loss, and rain loss (if applicable)
  - The recipient of the retransmitted signal connects to the PSTN for external communications.

- Three segments comprise a satellite system: space segment, user segment, and control segment
  - The space segment is composed of the satellite platform (the frame of the satellite) and the satellite payload (the operational service-providing equipment). The payload provides communications capabilities to the users
  - The user segment consists of the terminal equipment that transmits and receives signals to and from the satellite. MSS user terminals can range in size from a handheld telephone to a suitcase-sized or vehicle-mounted terminal. The size is dictated primarily by the technical capabilities of the terminal and the RF power output
  - The control segment is responsible for operating the satellite and providing overall network management. The control segment ensures that the satellite stays in the proper orbit, efficiently assigns transponders, adjusts power levels, allocates bandwidth, and steers antennas
  - Shown on the following page is a diagram of a satellite system with three different segments

SHOWN BELOW IS A DIAGRAM OF AN MSS SYSTEM INCLUDING SPACE, USER, AND CONTROL SEGMENTS



SATELLITE TOPOLOGIES ARE CATEGORIZED USING THREE DIFFERENT ORBITS: GEOSTATIONARY EARTH ORBIT (GEO), MEDIUM EARTH ORBIT (MEO), AND LOW EARTH ORBIT (LEO)

- Communications satellites rely on three different orbits: GEO, MEO, and LEO. With each unique orbit, a specific application can be used
  - GEO orbits are circular orbits oriented on the Earth's equatorial plane. In a geostationary orbit, the satellite appears stationary, i.e., in a fixed position, to an observer on the Earth
    - » In more technical terms, a geostationary orbit is a circular prograde orbit in the equatorial plane with an orbital period equal to that of the Earth; this is achieved with an orbital radius of 6.6107 Earth radii, or and orbital height of 35,786 kilometers (km) (22,236 miles), or roughly one tenth of the distance to the Moon
    - » The footprint of a typical geosynchronous satellite varies according to signal strength requirements; however, the LOS from an observer on Earth to the satellite is slightly less than half the distance around the globe
  - MEO orbits are circular orbits at an altitude of approximately 10,000 km (6,214 miles)
    - » The orbit period is about 6 hours; thus the maximum time during which an observer on Earth can view a satellite above the horizon is on the order of a few hours
    - » A global communications system comprised of MEO satellites requires a modest number of satellites in two to three orbital planes to achieve global coverage
    - » A prime example of an MEO constellation is the DoD-owned Global Positioning System (GPS)
  - LEO orbits are either elliptical or (more usually) circular with an approximate orbital altitude of 2,000 km (1243 miles)
    - » The orbital period at these altitudes varies between 90 minutes and 2 hours
    - » The radius of the footprint of a communications satellite in LEO varies from 3,000 to 4,000 km (approximately 1,900 to 2,500 miles)

IN THE FIRST 15 YEARS OF SATELLITE COMMUNICATIONS SYSTEMS, 6 AND 4 GHZ FREQUENCIES HAVE BEEN THE MOST HEAVILY USED MSS BANDS, HOWEVER, SINCE SPECTRUM IN THOSE FREQUENCY BANDS IS VERY LIMITED, RECENT TRENDS SHOW SATELLITES USING THE 1 TO 2 GHZ BANDS

- The 6 and 4 GHz uplink and downlink bands, also known as 6/4 bands, have been the most popular uplink and downlink frequencies because they offer the fewest propagation problems, decreased cost because of simplified design, and, historically, the ready availability of RF components for these frequencies
  - Reducing attenuation of radio waves by rain is a major advantage for selecting an RF satellite frequency in the 6/4 band; higher attenuation per unit distance occurs for frequencies above 10 GHz
  - Because sky noise is low at 4 GHz, it is possible to build receiving systems for that frequency with lower noise than for higher frequency systems
  - In addition, antennas of a given diameter can produce narrower beams at higher frequencies; therefore, regional satellites can be made more directive at the upper end of the frequency range, thus leaving the MSS satellites with the lower spectrum area

- The newest of all satellite providers use frequencies in the 1 to 2 GHz bands
  - Lower frequency ranges decrease the call capacity per satellite, however the attenuation is much lower
  - More satellites are needed to maintain a higher capacity
  - Equipment has an increased reliability due to the avoidance of rain attenuation common in systems above 10 GHz
  - Equipment is often less expensive since less power is needed to reach the satellite

OFTEN A LARGE NUMBER OF EARTH STATIONS SHARE ONE SATELLITE AND PROVIDE MANY INTERCONNECTING PATHS THROUGH ONE TRANSPONDER; THEREFORE MULTIPLE ACCESS TECHNIQUES MUST BE USED

- Time Division Multiple Access (TDMA) [3]
  - MSS satellites use this digital wireless technology to divide a narrow radio channel into framed time slots
  - The time slots are allocated to each user through a set of pre-coordinated time-allocation schemes between the satellite and all participating units

- Frequency Division Multiple Access (FDMA)
  - Mobile satellites have large frequency allocations that are divided into several smaller frequency channels
  - This technology enables a satellite to permanently assign a carrier frequency and a bandwidth around that carrier frequency to an attached Earth station, thus creating a large set of users at one time using separate multiplexers and demultiplexers on the satellite repeater

- Code Division Multiple Access (CDMA)[4]
  - This digital technology uses "spread spectrum" technology to break up speech into small, digitized segments and encodes them to identify each call. A large number of users can share the same band of spectrum, greatly increasing system capacity

[3] Qualcomm Inc. “About CDMA,” < http://www.qualcomm.com/ cda/tech/aboutcdma/ >. January 2001.
[4] Ibid.

VI. SMR, ESMR, AND MSS COMMUNICATION SERVICES

THIS SECTION DISCUSSES THE FOLLOWING TOPICS RELATING TO THE SPECIFIC SERVICES RELATIVE TO SMR, ESMR, AND MSS TECHNOLOGIES

- General costs of the services – Costs depict the expense of monthly or yearly service fees and the initial cost of setup and equipment
- Coverage – Coverage explains the service range of the equipment and/or the service provider
- Capacity and Congestion – Capacity and Congestion explain how many users can communicate at a time and how often the service may reach a capacity limit
- Security – Security describes the vulnerabilities and level of encryption or privacy for each communications system
- Handset Technology – Handset technology describes the functions, features, and battery life of an average handset in use today
- Miscellaneous technology – Technologies unique to each service are included for additional assistance

THE BASIC COSTS ASSOCIATED WITH SMR SERVICE ARE THE COST OF THE SERVICE AND THE EQUIPMENT PURCHASES OR LEASES

- Because SMR systems do not exist in mass markets, pricing will likely vary by region

- SMR customers typically pay equipment and service costs, which range from $15 to $20 per month per radio for unlimited usage

- Other communications services that can be used with SMR can be purchased depending on availability in certain areas
  - PSTN connections are possible using additional equipment connected to the base station console
  - Trunked systems that allow more than one channel of communication at a time include more complex equipment that may add costs
  - SMR systems are primarily used for voice communications; however, data services, such as facsimiles, paging and inventory tracking, credit card authorization, automatic vehicle location, fleet management, remote database access, and voicemail services, may be available

- In addition to service costs, subscribers usually must buy end-user radio equipment
  - SMR radios vary in appearance and often resemble a cellular telephone or sophisticated citizen band radio
  - The radios typically operate in a push-to-talk fashion, although dial-up is becoming more common
  - Prices can range from less than $200 to $1,000, depending on equipment features included and whether the equipment operates using analog or digital technology

BECAUSE THERE IS NO STANDARD PROTOCOL, NATIONAL SERVICE PROVIDER, OR COMMON TECHNOLOGY, SERVICE AVAILABILITY IS DEFINED BY EACH SERVICE PROVIDER'S CAPABILITIES IN A GIVEN AREA

- SMR coverage is limited compared with other commercial services due to a more limited number of base stations (creating a smaller service area) than that offered by ESMR providers

- SMR users may also experience coverage gaps similar to those in cellular telephony
  - Terrain or building interference can weaken or block signals
  - Rain and other environmental characteristics can weaken a signal
  - Interference can be caused by other nearby frequencies, power sources, or natural occurrences

- SMR customers may or may not compete with other users for access to the network
  - If the system is fully loaded and all channels are in use, users either receive a busy signal or calls are "queued" until a channel is free
  - SMR is not typically used by the mass market, so it may be less susceptible to surge effects than other services, such as cellular service or PCS
  - Some SMR systems offer a priority access capability, which may provide agencies with access to SMR during mission-critical tasks

- Unlike LMR, SMR services do not allow radios to communicate directly with each other (i.e., do not provide "talk around" service)
  - SMR radios must first communicate through the base station. Thus, if the SMR base station is damaged or malfunctions, users cannot communicate using SMR equipment

- The type of equipment being used can define capacity in a given system. If a trunked system is available, the number of channels available at a given time should be investigated

DIFFERENT SECURITY RISKS AND VULNERABILITIES ARE ASSOCIATED WITH ALL COMMERCIAL WIRELESS SERVICES

- Analog communications within an SMR network are the least secure of the networks examined in this report
  - Because analog communications operate by "broadcasting" audio between a mobile terminal and an antenna site, it is relatively easy to intercept and eavesdrop on communications
  - Analog communication is susceptible to "cloning" of radios
  - Analog communication service is extremely vulnerable to fraud

- Encryption is currently not available in standard SMR networks; however, encryption can be applied to some networks for users with specific requirements

TYPICAL SMR MOBILE AND PORTABLE RADIOS, ALTHOUGH SIMPLER, ARE SIMILAR TO PRIVATE LMR RADIOS

- Mobile radios consist of a vehicle-mounted unit, with a standard attached microphone. Shown in the table below are 3 types of SMR products that have a varied set of features

Features	Radio A	Radio B	Radio C
Multimode Mobile	X	X	X
Data Ready	X	X	X
Power Requirements	20 Watts	20 Watts	20 Watts
Trunked/Conventional	Both	Trunked	Trunked
Front Firing Speaker	X		
Ruggedized Design	X		
Improved Audio Quality	X		
Horn Alert		X	X
Call Out-of-Range Light		X	X
User-Programmable Scan Mode	X	X	X
Alphanumeric Display		X	X

- SMR radios functions such as dispatching and talk around capabilities are similar to LMR radios

- Portable radios are similar to mobiles; however, the output power is decreased and battery packs, chargers, and features are somewhat decreased

THE BASIC CATEGORIES OF ESMR COSTS INCLUDE THE PRICE OF A TELEPHONE, SERVICE FEES, AND CHARGES FOR ENHANCED FEATURES NOT INCLUDED IN A PLAN; AGENCY PACKAGE DEALS MAY ALSO BE AVAILABLE

- Plans usually include a one-time charge for setup and the cost of the telephone
  - A service plan is usually set up for monthly billing or as a yearly contract
  - Usage-based pricing typically covers a specified number of airtime minutes for the monthly service charge
  - Users pay incrementally, on a per-minute basis, for usage beyond the fixed limit
  - Costs for service may range from about $.10 per minute to $.15 per minute, depending on the plan used
  - Roaming or international calls may add cost
  - Plans quite often vary by demand, service provider, and region
  - Shown below are examples of widely used plans. Special package deals may vary

	Plan A	Plan B	Plan C	Plan D	Plan E	Plan F
Monthly Access Fee	$59.99	$79.99	$99.99	$129.99	$159.99	$199.99
Included Airtime (minutes)	400	600	900	1,200	1,500	2,000
Each Additional Minute	$0.35	$0.35	$0.25	$0.25	$0.25	$0.25
Direct Connect Private Call	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Group Call (per minute)	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15
Web Service	Free	Free	Free	Free	Free	Free
Nationwide Long Distance	Free	Free	Free	Free	Free	Free
Voice Mail	Free	Free	Free	Free	Free	Free
Shared Minutes Available	Included	Included	Included	Included	Included	Included

THE BASIC CATEGORIES OF COSTS INCLUDE THE PRICE OF A TELEPHONE, SERVICE FEES, AND CHARGES FOR ENHANCED FEATURES NOT INCLUDED IN A PLAN; AGENCY PACKAGE DEALS MAY ALSO BE AVAILABLE (CONT'D)

- Cost of telephones
  - The cost of telephones varies from $0 to approximately $500. The cost of the telephone depends on the package cost established by the service provider and the complexity of the telephone

Telephone Feature List	A	B	C	D	E	F
Features						
Voice activated Dialing					X	X
Speakerphone			X	X		
Dual-mode use				X		
Voice memos						X
Interchangeable face plate					X	
Speed dialing, Vibration Alert		X	X	X	X	X
Last 10 number check, missed call indicator, Quickstore, Multi-Language, Selectable Ring Styles	X	X	X	X	X	X
Available Services						
Two-Way Radio, Wireless Web, Voice Mail, Caller ID, Call Waiting, Call Hold	X	X	X	X	X	X
Three-way calling, Alternate Line Service		X	X	X	X	X
Alternate Line Service		X	X	X	X	X
Standby Battery Life (hours)	85	85	45	45	75	75
Talk Time Battery Life (minutes)	330	330	180	180	165	165

ESMR COVERAGE SPANS NEARLY THE ENTIRE CONTINENTAL UNITED STATES, ALTHOUGH SUBSCRIBERS MAY STILL EXPERIENCE GAPS IN SERVICE

- Coverage is established on the basis of potential users in a specified area
  - ESMR carriers may not provide coverage in rural areas away from major roadways because of low levels of demand, producing low potential revenue

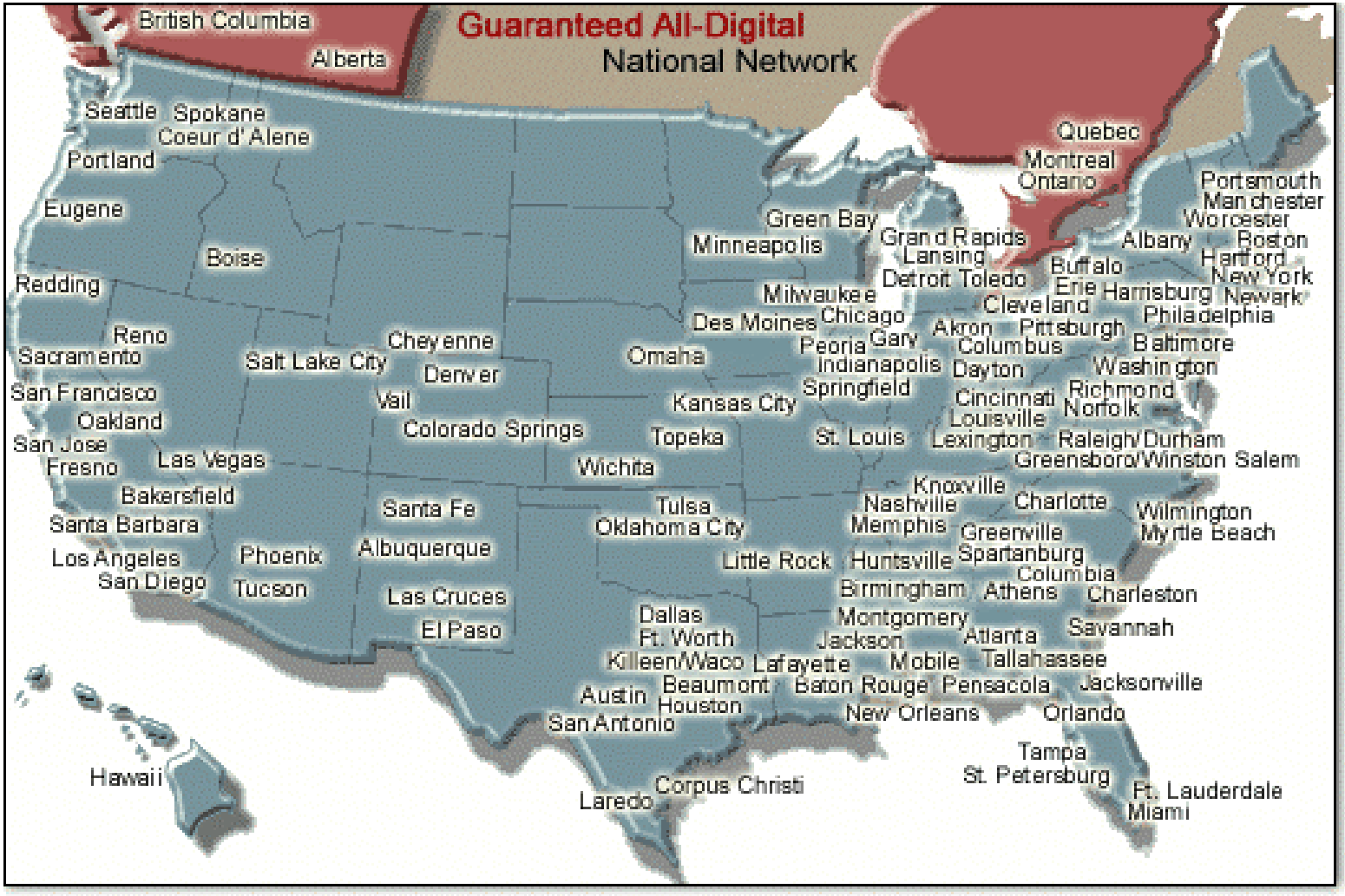
- Coverage gaps have several causes
  - Terrain or building interference can weaken or block signals
  - Rain and other environmental characteristics can weaken a signal
  - Interference can be caused by other nearby frequencies, power sources, or natural occurrences
  - As networks and service providers mature, the occurrence of these coverage gaps may be reduced

- Because ESMR uses a proprietary air interfacing technology, there is usually no direct interoperability with other service providers; however, some ESMR providers advertise nationwide availability

- Recent advances in telephone technology have enabled users to not only have nationwide coverage, but also the ability to roam in South America, Europe, Africa, and Asia. Federal public safety agencies could potentially use this feature during international investigations
  - Telephones using this technology are similar to cellular and PCS telephones with dual mode capabilities. The specialized telephones contain software that allows their use for both ESMR and GSM services

- Roaming is a technique that allows cellular telephones to function in another service provider's coverage area
  - A mobile telephone can identify another service provider's cell site and use the frequencies associated with that site if no home service is available
  - Roaming is usually more expensive but can be advantageous if coverage is limited
    - » The subscriber equipment can automatically choose the system with stronger coverage
  - ESMR, due to the unique air interfacing, does not allow roaming outside of a service provider's coverage area, meaning that the user equipment is not intended to operate with other providers. This limitation generally means that the subscriber uses a service provider's nationwide infrastructure as the home area, and therefore roaming is not needed

SHOWN BELOW IS AN EXAMPLE OF ESMR NATIONWIDE COVERAGE



- Courtesy of Nextel Communications Corporation

ESMR SUBSCRIBERS SHARE THE AIRWAVES AND MAY COMPETE FOR CAPACITY ON THE NETWORK; THEREFORE, AT TIMES, DEMAND AT A CERTAIN LOCATION WILL EXCEED CAPACITY

- Congestion occurs when all available channels are taken at a particular cell site
  - Call attempts cannot be made until resources (i.e., channels) are free

- Likely causes of congestion include the following
  - Major events such as sporting events, concerts, and business conferences
  - Natural or manmade disasters and other emergency response incidents
  - Rush hour (e.g., during the hours of 7–9 a.m. and 5–7 p.m.)

- Capacity is different for certain air interface technologies. ESMR subscribers use TDMA air interface for sharing bandwidth
  - A TDMA system uses a fixed set of spectrum for each base station, which provides connectivity to the PSTN
  - The spectrum is usually divided into 124 separate 200kHz channels
  - For each channel, the 200 kHz is shared among 8 simultaneous users by dividing the bandwidth into time segments
  - Capacity is defined by the number of channels multiplied by the number of simultaneous users. In an emergency scenario, an available channel is given to each user on a first-come, first-serve basis, independent of location or priority

CURRENT MAJOR ESMR PROVIDERS OFFER ENHANCED SECURITY CAPABILITIES TO THEIR USERS

- ESMR providers offer protection of communications and information from unauthorized access with Secure Sockets Layer (SSL) encryption, two-factor password protection, and secure archiving protocols
  - SSL is a commonly used protocol for managing the security of a message transmission on the Internet. The term "sockets" refers to the method of passing data back and forth between a client and a server program in a network or between program layers in the same computer. SSL uses the public-and-private key encryption system from RSA, which also includes the use of a digital certificate

- Digital telephone technology, such as GSM interface methods, are less likely to be intercepted using conventional scanning methods because of the digitally encoded nature of the transmission. Although this transmission scheme provides an added layer of protection, these communications technologies can still potentially be intercepted

ESMR USES PROPRIETARY INTERFACING TECHNOLOGY, WHICH GENERALLY INVOLVES USING A SINGLE MANUFACTURER THAT PRODUCES A SUITE OF TELEPHONES WITH VARIOUS CHARACTERISTICS SUCH AS SIZE, WEIGHT, SHAPE, BATTERY TECHNOLOGY, RANGE OF SERVICE, ENHANCED FEATURES, AND DISPLAY TYPE

- The size of an ESMR telephone is similar to a cellular or a PCS telephone. Telephones can be a one-piece construction or a two-piece flip style

- Battery life of the telephone ranges from 45 to 85 hours of standby time and 165 to 330 minutes of talk time. Various size batteries may also be available with each size telephone, providing a choice of size and weight versus depending on the desired time before charging

- Many enhanced features are available on each specific telephone. Certain features may be available only on certain telephones, or some features may be available but not included in the standard pricing. Listed below are several common features

Common Features	
Digital Two-Way Radio	Speakerphone
Mobile Messaging	Voice Activated Dialing
Voice Mail	Wireless Web
Call Waiting	Worldwide Service
Caller ID	Vibrating Call
Call Hold	Ruggedized
Quickstore Numbers	See-Through Display
Selectable Ring Styles	Alternate Line Service
Voice Memo Storage	Multiple Language
Phonebook	International Dialing
Datebook	Missed Call Indicator
Rapid Charging	Last 10 Numbers Received/Sent
Three-Way Calling	Changeable Face Plates

RECENT ADVANCES IN ESMR HAVE ENABLED DATA AND VOICE DISPATCH CAPABILITIES, WHICH PROVIDE A CENTRALIZED MEANS OF TRACKING AND MANAGING ACTIVITIES

- Dispatch functions may enable an agency to enhance its capabilities without the use of an expensive computer aided dispatch (CAD) system. A dispatcher in a central office can essentially log into a dispatch utility from a standard personal computer (PC) using a secure enabled browser
  - A dispatcher can relay instant messages to single or multiple users in the field
  - Mobile workers in the field can respond using the two-way communication capability built into the telephones
  - A computer can automatically send a text message to a user's telephone with the following functions:
    - » Notices – Notices can be sent to field personnel relating to tasks scheduled previously or on a real time basis that requires a user in the closest area
    - » Geographic zones alert – Geographic zones based on location information can route a specific user to a job requiring the closest person available
    - » Acknowledgements – Users can send a reply signal back to the central office, to confirm the new assignment
    - » Status reports – Users can also report to the central office on current job status at any given time
  - Attributes of a particular mobile worker can be associated with that user's identification. For example, bilingual employees or wheelchair equipped vehicles can be entered in using enhanced accessibility functions
    - » Dispatchers can assign jobs with these requirements and match the best user with the respective job
  - Voice communication is not required with the dispatch system because two-way text messaging is used

THE BASIC CATEGORIES OF MSS COSTS INCLUDE THE PRICE OF A TELEPHONE, SERVICE FEES, AND CHARGES FOR ENHANCED FEATURES NOT INCLUDED IN A PLAN

- Plans usually include a one-time charge for setup and the cost of the telephone
  - A service plan is usually set up for monthly billing or as a yearly contract
  - Usage-based pricing typically covers a specified number of airtime minutes for the monthly service charge
  - Users pay incrementally, on a per-minute basis, or an established price depending on the minutes used
  - Costs for service may range from about $.79 per minute to $1.29 per minute depending on the plan used
  - Additional charges may include a set monthly access fee and extra charges to calls outside the system, such as a standard PSTN phone
  - Shown below are examples of widely used pricing plans

	Minutes Used				
	1–49	**50–99**	**100–249**	**250–499**	**500+**
Monthly Access Fee	$19.95	$19.95	$19.95	$19.95	$19.95
Per Minute Voice or Data Rate Tiers	$1.29	$1.19	$0.99	$0.89	$0.79
Voice Mail	$9.95	$9.95	$9.95	$9.95	$9.95
Call Forwarding Access ($0.15 usage charge plus long distance charges)	Free	Free	Free	Free	Free
Customer Care Dialing	Free	Free	Free	Free	Free
Nationwide Long Distance	Free	Free	Free	Free	Free

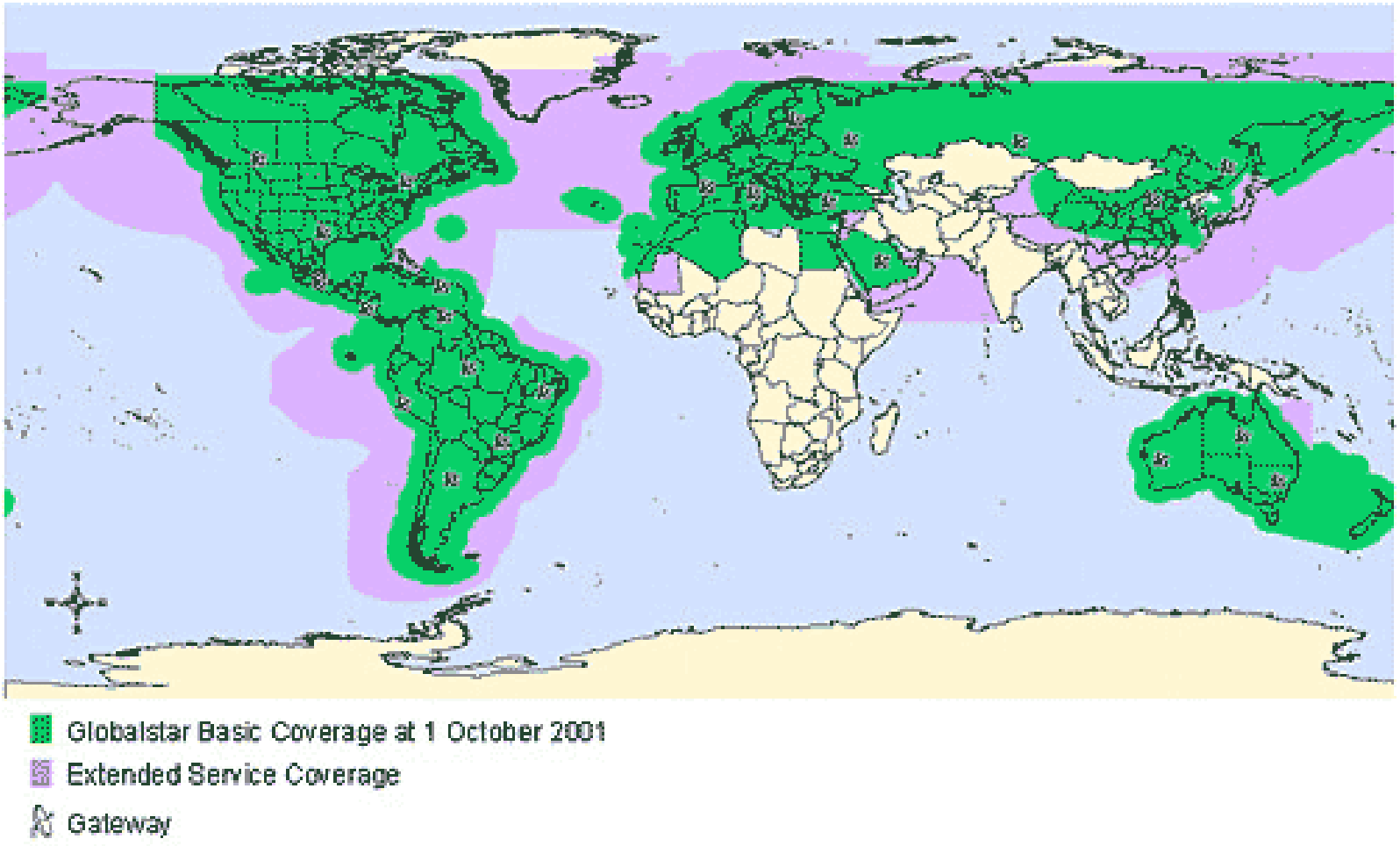
Activation Fee	$60.00
Monthly Access Fee	$20.00
Mobile to Mobile	$0.50/min
Mobile to PSTN Line	$1.50/min
Mobile to differing satellite telephone service	$12.50/min

RENTAL PURCHASING PLANS EXIST FOR EXTENDED EMERGENCY SERVICES NEEDS

- Satellite telephones can be rented for emergency needs that would require multiple telephones for extended periods of time in remote locations. The standard price list is as follows:

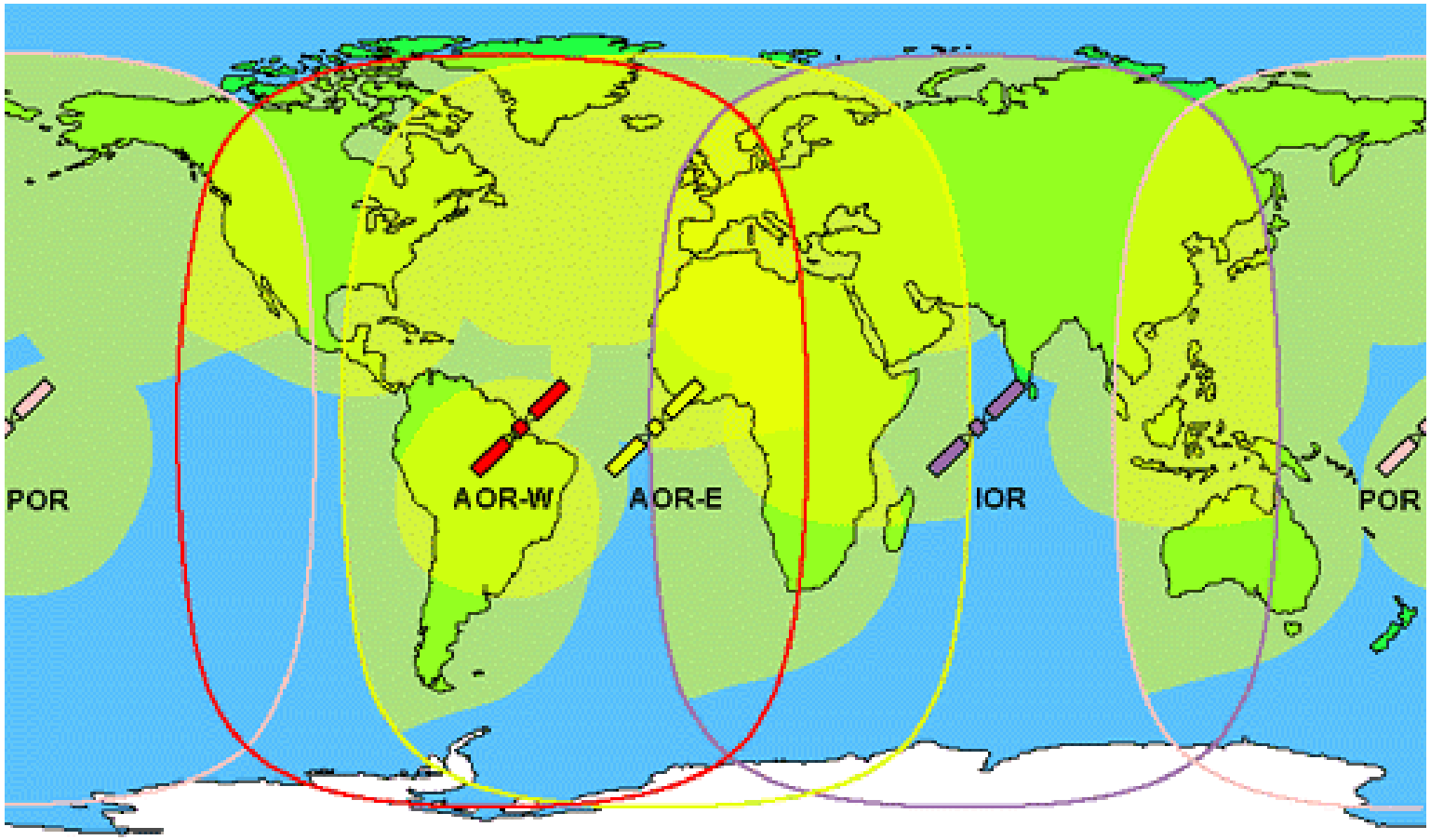
Equipment or Service	Cost
Rental of Telephone	$120.00 / week
Activated Security Card	Included
Cigarette Lighter Adapter	Included
Universal Charger	Included
External Magnetic Antenna and Adapter	Included
Leather Belt Holster	Included
Extra Battery	Included
Additional Days	$12.00/day
Data Kit	$1.20/day
Outgoing Satellite to PSTN Calls	$2.20/min
Outgoing Satellite Calls to Other Satellite Systems	$15.00/min
Outgoing Calls to Same Subscriber Telephones	$1.85/min
Data Calls	$2.20/min
Incoming Calls or Pages	Free

SHOWN BELOW ARE VARIOUS COVERAGE MAPS FOR MSS SATELLITE SYSTEMS



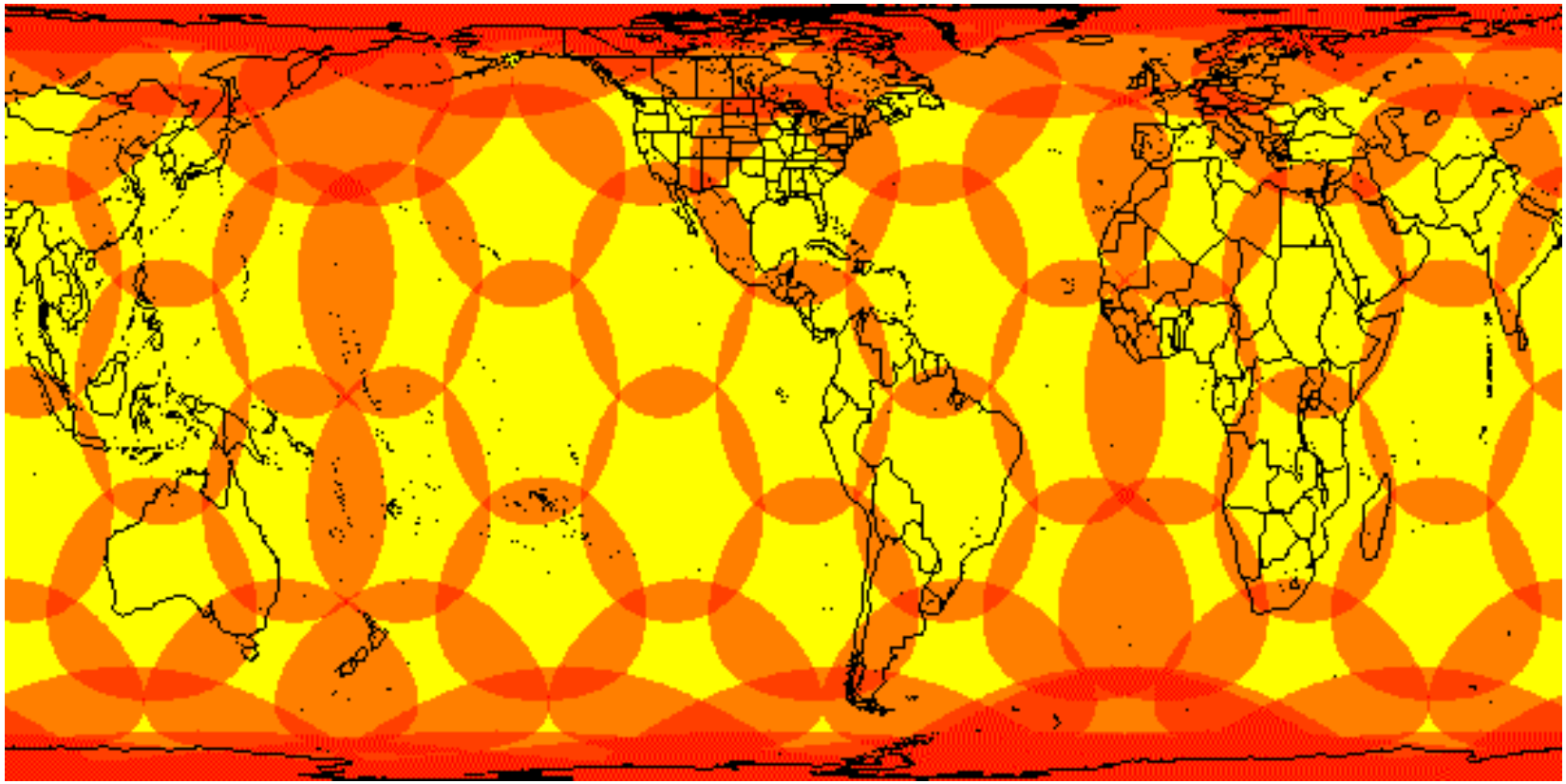
SHOWN BELOW ARE VARIOUS COVERAGE MAPS FOR MSS SATELLITE SYSTEMS (CONT'D)

- In the specific system shown below, the darkened circles indicate the footprint of coverage with respect to each satellite. Four satellites are shown below with footprints covering entire continents. The coverage shown on this page is for a MEO satellite constellation, whereas the coverage shown on the next page is for a LEO satellite constellation. Coverage for a GEO constellation is not shown because GEO satellites are not generally used for real-time voice communications due to issues associated with latency.



SHOWN BELOW ARE VARIOUS COVERAGE MAPS FOR MSS SATELLITE SYSTEMS (CONT'D)

- In the specific system shown below, the darkened circles indicate the footprint of coverage with respect to each satellite. One advantage with a LEO constellation over a MEO or GEO constellation is that there is less risk associated with system downtime due to single points of failure.



MSS SATELLITES ARE AVAILABLE TO OUTDOOR USERS BECAUSE OF THE CONSTANT LOS AVAILABLE AT ANY POINT ON THE GLOBE

- MSS coverage is available for use in any environment that has a clear view of the sky, although several factors may inhibit use at times
  - MSS handsets must have a direct LOS view with at least one satellite to function properly
  - System components, i.e., satellites, ground control stations, and user handsets, are susceptible to rare service interruptions
  - Handset users share the network infrastructure when making calls; therefore, ill effects similar to those experienced with cellular telephones are possible, particularly congestion issues due to high user call volume
  - Mobile communications satellites are also susceptible to system-level service outages. Although rare, when a satellite malfunctions, a user handset may have to wait for an operational satellite to move into position overhead before obtaining another signal
  - Astronomical effects can also affect service. Because satellites are not under Earth's protective atmosphere, they are more vulnerable to the Sun's solar flares or damaging debris in orbit around the Earth

COMMUNICATIONS USING SATELLITE TELEPHONE TECHNOLOGIES ARE LESS LIKELY TO BE INTERCEPTED, ALTHOUGH THESE COMMUNICATIONS TECHNOLOGIES STILL CAN BE AND HAVE BEEN INTERCEPTED

- Satellites using multiple access techniques such as FDMA, TDMA, and CDMA are encoded and less likely to be intercepted using conventional means
  - FDMA – This process separates uplink and downlink frequencies. By doing so, this separates the uplink and downlink conversations, rendering them less likely to both being intercepted
  - TDMA – Voices are digitally modulated and split into separate slices of time using proprietary schemes. Upon interception of a certain frequency, a time scheme must be known to separate the simultaneous conversations occurring at the same time on a specific channel
  - CDMA – This technology scheme employs multiple sections of bandwidth at a time, making interception even more difficult

- Satellite providers offer encryption tools for more secure communications
  - The external pieces of equipment attach to a separate transmitter and receiver for on-site encryption and decryption
  - An example of this type of secure communications uses a Harris CITADELTM CCX or Triple Data Encryption Standard (DES) algorithm with a 128-bit cryptographic key

THE MSS SUITE OF TELEPHONES HAVE SIMILAR COMMUNICATIONS CHARACTERISTICS TO CELLULAR TELEPHONES; HOWEVER, SEVERAL FEATURES MUST BE INCLUDED THAT SUPPORT SATELLITE CONNECTIVITY

- Because of the distance a signal must travel to reach satellites, telephones must be equipped with high gain antennas and/or a larger power output to effectively communicate with a satellite. Thus, satellite telephones are slightly larger than cellular telephones

- A few satellite telephones are compatible with regional or national cellular or ESMR telephones. These telephones automatically use terrestrial services when available

- Shown below is a chart of many popular satellite telephone features

Popular Features	
Dual-Mode Capable (Satellite & Terrestrial)	Memory Scroll
Quick Access Interface	One-Touch Dialing
Hands Free Operation	Selectable Ring Tones
Water, Shock, and Dust Resistant	Last 10 Numbers Dialed
Data Capable (RS232 Adapter)	Keypad Disable
Multi-Language Capable	Unanswered Call Indicator
Crisis Calling	100 Name/Number Memory Storage
Specialized Ring Tones/Vibration Alerts	Subscriber Identity Security Card
Illuminated Display	Battery Meter/Warning Light
Auto Redial	Call Restrictions/Locking feature
Call Forwarding	Programmable and Audible Call Timer
Clear Last/All Digits	External Antenna Connection
International Access Key Sequence	AC/DC Power Adapter
Numeric and Text Mailbox	Call Barring
Text Messaging	Signal Strength Meter
Low Battery Warning	

VII. SUMMARY

PUBLIC SAFETY AGENCIES THAT NEED A COMMUNICATIONS BACKUP, EITHER FOR EMERGENCY OR ADMINISTRATIVE USE, HAVE SEVERAL OPTIONS FOR COMMERCIALLY PROVIDED WIRELESS SERVICES, BUT SHOULD CONSIDER SEVERAL FACTORS WHEN PLANNING TO IMPLEMENT THESE SERVICES

- When choosing a service, agency planners should compare the capabilities of the currently used system with the stated capabilities of the new service. The following questions should be asked regarding these capabilities:
  - Coverage—Will the new service improve any communications "dead spots" in the current jurisdiction? Will the agency need service extending outside the current infrastructure coverage area? Are current services generally used indoor, outdoor, or both, and will introduction of the new service affect the agency's system needs?
  - Capacity—Will field personnel use the new service to perform administrative calls, thus expanding current communications resources? Will the new resources be capable of serving as a backup during emergencies, and will they need to be?
  - Security—Are the agency's current communications encrypted? If so, will the new services create a breach of security when used for certain tasks?
  - Handset and service technology—Will the equipment and system resources create a set of easy-to-use tools to assist a field officer (i.e., are the specific enhancements needed or available from the new service)? Are all the specific features available for the public safety agency's use?
  - Reliability—Has the service in question been proven in the field with other agencies, and are there success stories that reinforce this?
  - Interoperability—Can this service be integrated into the current system if the need arises? Is there a dual or tri-mode telephone that can connect to multiple services, depending on the current location?
  - Cost—Are the stated capabilities sufficient when considering the entire cost of the service?

- Many different commercial voice communications services exist within the United States. Each technology has unique features that differentiate themselves from other services. Beyond the general overview this report provides, the reader is encouraged to conduct further reading and research according to the considerations highlighted

APPENDIX A—BIBLIOGRAPHY

THE FOLLOWING REFERENCES WERE USED IN PREPARING THIS REPORT

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APPENDIX B—ACRONYMS

AM	Amplitude Modulation
ARFCN	Absolute Radio Frequency Channel Number
CAD	Computer-Aided Dispatch
CARTS	Cost, Availability, Reliability, Technology, Security
CDMA	Code Division Multiple Access
DES	Data Encryption Standard
DoD	Department of Defense
EA	Economic Area
ESMR	Enhanced Special Mobile Radio
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GEO	Geostationary Earth Orbit
GHz	Gigahertz
GPS	Global Positioning System
GSM	Global System for Mobile Communications
ID	Identification
kHz	Kilohertz
km	Kilometer
LEO	Low Earth Orbit
LMR	Land Mobile Radio
LOS	Line of Sight
MEO	Medium Earth Orbit
MHz	Megahertz
MSC	Mobile Switching Center
MSS	Mobile Satellite Service
NASA	National Aeronautics and Space Administration
PC	Personal Computer
PCS	Personal Communications Services
PMO	Program Management Office
PSTN	Public Switched Telephone Network

PSWN	Public Safety Wireless Network
RF	Radio Frequency
SMR	Special Mobile Radio
SSL	Secure Sockets Layer
TDMA	Time Division Multiple Access
UHF	Ultra High Frequency
VHF	Very High Frequency